MICROCOPY RESOLUTION TEST CHART

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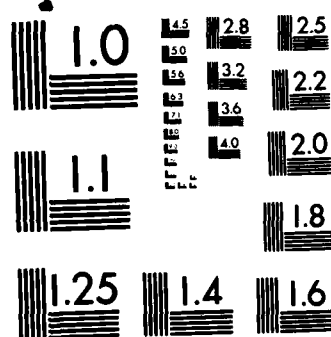
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SCIENTIFIC AND TECHNICAL REPORT

FOURTH QUARTERLY STATUS REPORT

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Microprocessor is a type of complex sequential machine. The current approach is to test microprocessor by instruction execution. Generally, before executing an instruction-under-test, we have to write certain data into some registers, and after executing the instruction, we have to read the contents of the registers. Therefore, if the write or read instruction is faulty, we may not be able to test the instruction-under-test. To solve this problem, Thatte and Abraham [1] have to label instructions and define test order in detail before testing. In addition, they do not consider the partial execution of an instruction. So one of the instruction decoding faults $I_j / I_j + I_k$ is assumed that, instead of executing I_j, both instructions I_j and I_k are executed to completion. This raises the problem of practicality.

Abraham and Packer's method [2] is simple, but their "register read test" procedure does not guarantee the correctness of write and read register functions for any data.

In our work, we consider the write and read register function as a kernal of a microprocessor; similar to a sequential machine, and we use the checking experiment to verify the kernal based on the fault models. Then we use the kernal for testing other instructions.

Our approach consists of three steps:

Step 1: Establish the fault model for representing functional faults

Step 2: Determine the requirement for test generation.

Step 3: Based on the requirements, develop testing procedures.

We shall briefly describe the fault model and the requirements. First of all, we need to establish a fault model for a microprocessor.

The semiconductor manufacturers consider the circuit diagrams of microprocessor chips proprietary information and therefore, these diagrams are not available to users. The only information we can get is from manufacturer's data books and application notes, including the architecture, the instruction set of a microprocessor, and so forth, so that microprocessor testing here is a functional testing.

The functions of a microprocessor are mainly performed by instruction execution. The functions of an instruction can be described by RTL (Register Transfer Language) [3] . We consider here that an instruction consists of a series of RTL statements. The typical statement is defined as

$$(\text{conditions}), \quad D \leftarrow f\ (S_1,\ S_2, \ldots, S_i \ldots)$$

where D - destination

S_i - source

$f\ (S_1, S_2, \ldots, S_i, \ldots)$ - operation

A microprocessor usually can be divided into two sections: the data processing part, and the control part. Here we only discuss testing instructions of a microprocessor. The sequencing of RTL statements reflects the control part of a microprocessor. The RTL statement itself is corresponding to the data processing part as well as the control part. We consider two types of faults.

A. Data Processing Faults

   1. Data storage fault (R)/(R)' i.e. due to a fault, the content of register R is changed to a different value. It means register element fault and includes stuck-at and pattern sensitive faults.

2. Data transfer fault $\leftarrow/\leftarrow'$

   The fault appears at a source or destination transfer path
   and includes stuck-at and bridging fault.

3. Data manipulation fault $(f)/(f)'$

   This means operation execution fault, with this type of fault,
   the operation f is executed, but the result of execution is wrong.

B. Control Faults

   This kind of fault invloves register decoding faults, instruction
   decoding faults and other control faults. Register decoding faults
   means the missing and changing of the selected register, and selection
   of extra register, i.e. R/ϕ, R/R' and $R/R+R'$ respectively. For
   instruction decoding faults, we consider that an instruction can be
   executed partially. It means missing and changing of selected operation
   and selecting of extra operation in RTL. In that case, the instruction
   decoding fault may be I_j/ϕ, $I_j/\Delta I_j$, $I_j/\Delta I_k$, I_j/I_k, $I_j/\Delta I_j + \Delta I_k$,
   $I_j/I_j + \Delta I_k$, $I_j/I_j + I_k$, and so forth, where ΔI means part of instruction I.
   In fact, the register decoding faults can be considered as instruction
   control faults, i.e. $R/\phi \ \epsilon \ I_j/\phi$, $R/R' \ \epsilon \ I_j/I_k$, $R/R+R' \ \epsilon \ I_j/I_j + I_k$,
   where I_j, I_k are transfer instructions among registers. In addition,
   The control faults also include instruction execution sequence faults,
   condition faults and so on.

   We will define the above control faults at the RTL level. Let f
   denote $D \leftarrow f \ (S_1, S_2, \ldots)$, which is an operation on the instruction-
   under-test, f' denote $D' \leftarrow f' \ (S_1', S_2', \ldots)$, which is unexpected
   (faulty) operation, where source and destination may be registers or

external busses. In the following, without special explanation, the register means register itself or external bus.

We now define three types of control faults.

1) f/ϕ - No operation is executed

2) f/f' - Instead of performing the operation of f, another operation f' is executed. It contains two subtypes of faults.

    2-1) Df/f' : Here D means that Registers D and D' are different and the fault is f/f'.

    2-2) Sf/f' : S denotes that Registers D and D' are the same

3) $f/f+f'$ - In addition to operation f, another operation f' is also executed. It can be subdivided as follows: Firstly, Register D and D' are different.

    3-1) $Df/f+f'$: The results of f and f' do not affect each other

    3-2) $Df/f'f$: The result f' affects the result of f and the execution order is

        1. $D' \leftarrow f' (S_1', S_2',...)$

        2. $D \leftarrow f (S_1, S_2,...,D'*)$

        where register without * denotes its content before executing the operation; register with * denotes its content after executing the operation.

    3-3) Df/ff' : The result of f affects the result of f' and the execution order is

        1. $D \leftarrow f(S_1, S_2,...)$

        2. $D' \leftarrow f'(S_1', S_2', ...,D*)$

        Secondly, Register D and D' are the same, i.e. D'=D.

        When the results of f and f' do not affect each other, if the execution order is f', f, the fault does not affect an instruction execution. If the execution

order is f,f', it is the same as the case with the fault Sf/f'.

3-4) Sf/f'f: The result of f' affects the result of f and the execution order is

1. $D \leftarrow f' (S_1',S_2',...)$
2. $D \leftarrow f (S_1,S_2,...,D^*)$

3-5) Sf/ff': The result of f affects the result of f' and the execution order is

1. $D \leftarrow f(S_1,S_2,...)$
2. $D \leftarrow f' (S_1',S_2',...,D^*)$

3-6) Sf/fLf': Both f and f' are executed at the same time

$$D \leftarrow f(S_1,S_2,...)$$
$$D \leftarrow f'(S_1',S_2',...)$$

In this case, the final content of the destination D is the composite value of both results of f and f', i.e. $f(S_1S_2,...) L f' (S_1',S_2',...)$, where symbol L denotes logical AND or logical OR depending on circuit implementation.

Note that the above control faults can be at any place in an instruction execution sequence.

From the above classification of control faults, we can obtain several requirements for testing these faults.

Let V_i denote the data value of a register i, any register can be the source or the destination for a RTL operation. So register values can also be named VS_i (operand in the source register S_i), VD (operand in the destination register D), and VD* (result of operation f in the destination register D). For an unexpected operation, we have VS_i', VD', and VD'*.

First of all, for testing any operation f, we require the following:

Q1. $f(VS_1, VS_2, ...) \neq VD$.

This requirement, Q1, means that a data which is different from the result of operation f is stored in the destination register D. If after operation f, the content of D is not changed to the expected value, then the operation f is incorrect. This test requirement can cover faults f/ϕ and Df/f'. For other faults, we need additional requirement as follows.

For fault Sf/f', the results of f and f' should be different.

Q2. $f(VS_1, VS_2, ...) \neq f'(VS_1', VS_2', ...)$

For faults $Df/f+f'$ and $Df/f'f$, we need only to detect the extra operation f'. The requirement is given below.

Q3. $f'(VS_1', VS_2', ...) \neq VD'$

For fault Df/ff', the extra operation f' is detected by the following requirement.

Q4. $f'(VS_1', VS_2', ..., f) \neq VD'$, where $f = f(VS_1, VS_2, ...)$

For fault $Sf/f'f$, the incorrect result of f due to the fault should be different from the correct one.

Q5. $f(VS_1, VS_2, ..., f') \neq f(VS_1, VS_2, ..., VD)$, where $f' = f'(VS_1', VS_2', ...)$

For fault Sf/ff', similarly, we require the following.

Q6. $f'(VS_1', VS_2', ..., f) \neq f(VS_1, VS_2, ...)$, where $f = f(VS_1, VS_2, ...)$

For fault $Sf/\!\!\!\!\!\;£_L$ f', the composit of both results of f and f' should be different from the correct result of f.

Q7. $f(VS_1, VS_2,...) \; L \; f'(VS_1', VS_2',...) \neq f(VS_1, VS_2,...)$

Based on the above seven requirement, we shall develop procedure for testing control faults on microprocessors.

[1] S.M. Thatte and J.A. Abraham, "Test Generation for Micro-processors", IEEE Trans. on Computers, C-29, N.6, June 1980, pp. 429-441.

[2] J.A. Abraham and K.P. Parker, "Practical Microprocessor Testing: Open and Closed Loop Approaches", IEEE Compcon, Spring 1981, pp. 308-311.

[3] S.Y.H. Su and U.I. Hsieh, "Testing Functional Faults in Digital Systems Described by Register Transfer Language", Journal of Digital Systems, Vol. 6 No. 2/3, summer/fall 1982, pp. 161-184. Also in proceedings of 1981 International Test Conference, pp. 447-457.

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